CHAPTER 9

OVERVOLTAGE PROTECTION

Section I-CONSIDERATIONS

9-1. Overvoltage protection.

This chapter describes the maintenance and repair of protective devices installed to limit transient over-voltages on lines. Abnormal voltages are caused most frequently by lightning, but system disturbances can also cause damaging voltage surges.

9-2. Lightning-induced voltage surges.

Overhead lines are extremely vulnerable to direct strokes or to induced voltage influences. Underground systems derived from aerial lines may also be affected.

a. Causes. Lightning results from the potential difference between clouds or between a cloud and earth. A lightning stroke may be in direct contact with an electric line and equipment. The charged clouds of a passing lightning storm may also cause an electrostatically induced voltage.

b. Protection. The high voltage of a lightning surge, imposed on lines and devices without surge protection, will flash over the insulation in the majority of cases. Where flashover occurs, through air or on insulators, it rarely causes permanent damage, but flashover occurring through the solid insulation on equipment or cable can result in permanent damage.

9-3. System operating voltage disturbances.

Transferring a system from one operating condition to another may generate a short-time transient overvoltage, known as a switching surge. A line-to-ground fault may increase the line-to-ground voltage of the unfaulted phases. An overvoltage results when resonance occurs from single-pole switching of three-phase circuits. Accidental contact with a higher-voltage system may cause an overvoltage. Forced-current zero interruptions, improperly applied, may cause a high transient voltage. The protective devices discussed for lightning-induced surges will also protect the system from these system-generated over-voltages.

9-4. Surge limiting protective device requirements.

A surge limiting protective device must limit transient over-voltages or surge voltages that could damage apparatus. The device must bypass the surge to ground and discharge severe surge currents of high magnitude and long duration without injury. The device must continuously withstand the rated power voltage for which it is designed. The device's protective ratio is the maximum surge voltage it will discharge, compared to the maximum crest power voltage it will withstand following discharge. Surge arresters provide the most accepted method of surge limiting protection, since they provide the highest degree of surge elimination. Other methods include shielding lines and equipment from direct lightning strokes; and providing devices designed to divert or change the wave form of the surge, such as protective gaps, surge capacitors, and bypass resistors.

Section II-SURGE (LIGHTNING) ARRESTERS

9-5. Definition of a surge arrester.

A surge arrester is a protective device for limiting surge voltages on equipment by discharging or bypassing surge current. Surge arresters allow only minimal flow of the 60-hertz-power current to ground. After the high-frequency lightning surge current has been discharged, a surge arrester, correctly applied, will be capable of repeating its protective function until another surge voltage must be discharged.

9-6. Types of surge arresters.

Surge arresters used for protection of exterior electrical distribution lines will be either of the metal-oxide or gapped silicon-carbide type. Expulsion-type units are no longer used.

a. Metal-oxide type. A metal-oxide surge-arrester (MOSA) utilizing zinc-oxide blocks provides the best performance, as surge voltage conduction starts and stops promptly at a precise voltage level, thereby improving system protection. Failure is reduced, as there is no air gap contamination possibility; but there is always a small value of leakage current present at power frequencies. Therefore, the arrester's maximum power-frequency continuous operating voltage (MCOV) can not be exceeded.

b. Gapped silicon-carbide type. Silicon-carbide has more nonlinearity than zinc-oxide. Without a gap the increase in leakage current, because of this nonlinearity, would soon burn out the arrester. A gap prevents burnout, but it does mean that the arrester will not operate until the gap sparks over.

As the sparkover voltage of a gap varies with the atmospheric pressure, the protective characteristics of arresters are affected by the altitude at which they are installed. Standard arresters are considered suitable for altitudes up to 6,000 feet.

c. Selection. Both types do the same job, but the need for selection of higher voltage levels for the silicon-carbide type means the protection is slightly less. When gapped type arrestors fail, consider replacing them with the metal-oxide type.

d. Equivalence. ANSI/IEEE C62.11 provides an MCOV rating and a corresponding duty-cycle voltage rating for MOSA units. The duty-cycle rating is based on the familiar voltage ratings of ANSI/IEEE C62.1, long used for the silicon-carbide design.

9-7. Classification of surge arresters.

ANSI/IEE C62.1 classifies arresters as station, intermediate, distribution, and secondary types. The best (lowest) available protective level and energy-discharging capability is provided by the station type with successively poorer (higher) protection levels for the other classifications. For distribution arresters, ANSI/IEEE C62.11 defines a normal-duty and a heavy-duty type, dependent upon the test severity. Heavy-duty arresters are more durable and generally have lower protective characteristics.

9-8. Maintenance of surge arresters.

Modern surge arresters require little operational maintenance and the degree to which such maintenance can be done is normally limited by lack of adequate test equipment. This limits surge arrester maintenance to visual inspection and simple electrical tests. It is recommended that units found to be defective be replaced rather than repaired: Where an arrester is composed of two or more individually complete units, each unit should be tested separately. Thus, a bad unit may readily be replaced and the good units retained. Surge arresters are almost always applied with one terminal connected to an electrically energized source and one terminal to ground. No work should be done, or contact made with surge arresters, when connected to the energized source.

a. Visual inspections. Visual inspection should be made periodically to ensure that:

(1) The line lead is securely fastened to the line conductor and the arrester.

(2) The ground lead is securely fastened to the arrester terminal and ground.

(3) The arrester housing is clean and free from cracks, chips, or evidence of external flashover.

(4) The arrester is not located in such a manner as to be subject to:

(a) Damaging fumes or vapors.

(b) Excessive dirt or other current-conducting deposits.

(c) Excessive humidity, moisture, dripping water, steam, or salt spray.

(d) Abnormal vibrations or shocks.

(e) Ambient temperatures in excess of 40 degrees C.

(5) Any external gaps are free from foreign objects and set at proper spacings.

b. Electrical tests. Visual inspection will not always detect a damaged arrester. Interior damage may result from a broken element, presence of moisture, a severe direct lightning stroke, or the use of an arrester with an incorrect rating. Sometimes these conditions will cause radio interference. Electrical tests, to detect inferior arrester units, may be made either in the field or shop. Tests must be made strictly in accordance with manufacturer's recommendations, and the results interpreted in line with manufacturer's criteria.

(1) *Power factor tests.* Each type and class of lightning arrester has a specific power factor when new. Periodic testing of a unit will show little deviation from the original (when new) power factor, so long as it remains in good operating condition. A major deviation from the original value indicates that the arrester has been mechanically damaged or contains moisture.

(2) *Megger tests.* A megger test can be made to provide additional information on the condition of an arrester. Such a test may indicate shorted valve elements in valve-type arresters.

(3) *Operation tests.* Electrical tests to determine 60-hertz breakdown and leakage current may be made in the field or shop, but must be made cautiously so as to avoid damage to the arrester. It is questionable whether these tests can be justified for military installations, where the number of arresters potentially subject to such tests is relatively small.

Section III-OTHER DEVICES

9-9. Surge shielding devices.

Shielding devices, such as lightning rods (air terminals), lightning masts, and overhead ground wires, are installed for the purpose of diverting lightning strokes from structures and equipment where more than surge arrester protection is justified.

a. Maintenance. Maintenance should ensure proper ground connections having minimal resistance. All supports and device clamps used in the shielding installation should be checked for rigidity, as insecure mountings may cause a mechanical failure. Periodically inspect the structures to ascertain that shielding devices have not been seriously damaged by previous discharges.

b. Construction. Copper, copper-clad steel, galvanized steel, or a corrosion-resistant metal alloy are all materials used in the construction of shielding devices.

9-10. Surge capacitors.

Surge capacitors are wave-shaping devices which produce a change in the lightning surge's waveform after it is imposed on an electrical system.

a. Use. In general, a surge capacitor is connected in parallel with a surge arrester for protection of the turn-to-turn insulation of rotating machinery, such as motors and generators.

b. Maintenance. See chapter 13 for capacitor maintenance.

9-11. Surge protective gaps.

Protective gaps (sometimes referred to as rod gaps) normally consist of two electrodes, spaced in the air at a specific distance, with one electrode connected to ground and the second electrode to the line potential. Electrodes may be of various sizes and shapes and are generally made of conventional lightning rod material.

a. Application. Protective gaps may be installed on substation structures in conjunction with line switches, or as an integral part of equipment bushings. The spacing between the electrodes is based on coordination of the protective characteristics of the gaps with other protective devices in a station. On some installations, gaps may serve as the primary surge protective device.

b. Maintenance. Protective gaps are installed with a specific separation between the electrodes. Severe electrode burning, resulting from lightning or system overvoltage discharges, may require a readjustment of gap spacing. Maintain proper spacing and keep electrodes free from burrs and sharp protrusions.

9-12. Surge bypass resistors.

A bypass resistor is a device containing nonlinear resistance material, in which the current varies as a power of the applied voltage. When a surge voltage occurs, the resistance of this device is decreased to divert the surge current around the protected winding.

a. Application. Bypass resistors are normally applied for the protection of turn-to-turn insulation of series-connected windings in such apparatus as regulators, autotransformers, and reactors. Bypass resistors are also useful to reduce switching surges on transmission lines, where the substantial surge reduction provided outweighs their cost.

b. Maintenance. If bypass resistors are mounted in air, any accumulation of dust particles between resistance elements should be removed periodically using dry compressed air. Proper clearances must be maintained to allow for free air circulation.